UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MAR 23 1995

OFFICE OF
SOLID WASTE AND EMERGENCY
RESPONSE

<u>MEMORANDUM</u>

SUBJECT: Update #2 to Removal Action Levels

FROM: John E. Riley, Acting Director
Emergency Response Division

TO: Removal Managers, Regions 1-10

My office has completed an updated table of numeric action
levels for contaminated drinking water sites. This table was
originally published as an attachment (dated May 1993) to Direc-
tive 9360.1-02 (October 25, 1993). The directive described the
new methodology used by OERR to calculate removal action levels
(RALs) in drinking water.

Using the methodology established in the 1993 directive, we
have re-evaluated the table based on the most recent Office of
Water's Drinking Water Regulations and Health Advisories (Novem-
ber 1994), IRIS (March 8, 1995), and HEAST (9200.6-303(94-1) and
supplement 9200.6-303(94-2)).

As á result of changes to the source materials, we revised
the RALs for three chemicals: chloral hydrate, dimethyl phthal-
ate, and metolachlor. The DWEL and RAL for dimethyl phthalate
have been removed because the RfD/RfC Work Group last year
decided that the oral RfD, which was reported in IRIS and HEAST,
is not verifiable. No new chemicals have been added to the table
at this time.

This table represents the latest available information on
these chemicals, and supersedes Update #1, which was issued on
September 22, 1994. We have attached copies of the table in both
hard copy and electronic (WordPerfect 5.1) forms. Please ensure
that copies of this table are circulated promptly to all Regional
staff involved with removal actions. If you have any questions
on this updated table, please contact Scott Maid at 703-603-8723.

Attachments

NUMERIC REMOVAL ACTION LEVELS FOR CONTAMINATED DRINKING WATER SITES

Tables

Emergency Response Division
Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency
Washington, DC 20460

March 1995

Table Acronyms

CAS #   Chemical Abstract Number

DWEL   Drinking Water Equivalent Level (calculated by multiplying the oral RfD by 70 kilograms (adult body weight) and dividing by the average volume of water (2 liters) consumed per day)

Longer-term HA (Child)   Drinking Water Health Advisory for 10 kg child consuming 1 liter water per day for up to 7 years

MCL   Maximum Contaminant Level (National Primary Drinking Water Standard)

MCLG   Maximum Contaminant Level Goal

MFL   Million Fibers per Liter

Treat. Tech.   MCL is based on the capability of the treatment technology

URTH-STAR   Draft Short-term Risk Level (STAR) recommended for an Unreasonable Risk to Health (URTH) under Safe Drinking Water Act

NUMERIC REMOVAL ACTION LEVELS FOR CONTAMINATED DRINKING WATER SITES
PRIMARY DRINKING WATER STANDARDS AND HEALTH ADVISORIES
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Chemical ORGANICS	CAS #	Cancer Risk — Cancer Group	Cancer Risk — 10^{-4} Cancer Risk (µg/L)	Standards and Health Advisories — DWEL (µg/L)	Longer-term HA (Child) (µg/L)	MCL / MCLG (µg/L)	URTH -STAR- Level (µg/L)	Superfund Removal Action Level (µg/L)
Acenaphthene	83329	—	—	2,100	—	—	...	2,100
Acetone	67641	D	—	3,500[a]	—	---	...	3,500
Acifluorfen (Tackle)	62476599	B2	100	400	100	— / 0		100
Acrylamide (2-Propenamide)	79061	B2	1	7	20	Treat. Tech. / 0	1	1
Acrylonitrile	107131	B1	6	—	—	— / 0	--	6
Adipates (Diethylhexyl)	103231	C	3,000	20,000	20,000	400 / 400	---	4,000
Alachlor	15972608	B2	40	400	---	2 / 0	40	40
Aldicarb (Temik)	116063	D	—	35	—	7 / 7	—	35
Aldicarb sulfone	1646884	D	—	35	—	7 / 7	- -	35
Aldicarb sulfoxide	—	D	—	35	—	7 / 7	....	35
Aldrin	309002	B2	0.2	1	0.3	—		0.2
Ametyrn	834128	D	—	300	900	—	---	300
Ammonium sulfamate	7773060	D	—	8,000	20,000	—		8,000
Anthracene	120127	D	—	11,000	—	—	—	11,000
Atrazine	1912249	C	—	200	50	3 / 3	30	30
Baygon	114261	C	—	100	40	—	---	40
Bentazon	25057890	D	—	90	300	— / 20	..	90
Benz(a)anthracene	56553	B2	—	—	—	0.1 / 0	—	0.1
Benzene	71432	A	100	- -		5 / 0	100	100
Benzo(a)pyrene	50328	B2	—	—	—	0.2 / 0	....	0.2
Benzo(b)fluoranthene	205992	B2	—	—	—	0.2 / 0	---	0.2
Benzo(k)fluoranthene	207089	B2	—	—	—	0.2 / 0	-	0.2
bis-2-Chloroisopropyl ether	108601	D	—	1,000	4,000	--		1,000
Bromacil	314409	C	—	5,000	3,000	---	---	3,000
Bromochloromethane	74975	D[a]	---	500	1,000	--	..	500
Bromodichloromethane	75274	B2	60	700	4,000	100 (80[b]) / 0	- -	100
Bromoform	75252	B2	400	700	2,000	100 (80[b]) / 0		400

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PRIMARY DRINKING WATER STANDARDS AND HEALTH ADVISORIES
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Chemical ORGANICS	CAS #	Cancer Risk		Standards and Health Advisories				Superfund
		Cancer Group	10^{-4} Cancer Risk (µg/L)	DWEL (µg/L)	Longer-term HA (Child) (µg/L)	MCL / MCLG · (µg/L)	URTH -STAR- Level (µg/L)	Removal Action Level (µg/L)
Bromomethane (Methyl bromide)	74839	D	—	40	100	—	—	40
Butanone (2-) (see Methyl ethyl ketone)								
Butyl benzyl phthalate	85687	C	—	6,000	—	100 / 0	--	6,000
Butylate	2008415	D	—	2,000	1,000	—	---	1,000
Carbaryl	63252	D	—	4,000	1,000	—	—	1,000
Carbofuran	1563662	E	—	200	50	40 / 40	50	50
Carbon tetrachloride	56235	B2	30	30	70	5 / 0	30	30
Carboxin	5234684	D	—	4,000	1,000	---	---	1,000
Chloral hydrate (Trichloroacetaldehyde monohydrate)	302170	C	—	60	200	60^c / 40	—	60
Chloramben	133904	D	—	500	200	—	—	200
Chlordane	57749	B2	3	2	—	2 / 0	2	2
Chlorobenzene (see Monochlorobenzene)								
Chlorodibromomethane (Dibromochloro-methane)	124481	C	—	700	2,000	100 (80^b) / 60	—	600
Chloroform (Trichloromethane)	67663	B2	600	400	100	100 (80^b) / 0	---	100
Chloromethane (Methyl chloride)	74873	C	—	100	400	—	--	100
Chlorophenol (2-)	95578	D	—	200 ·	50	—	---	50
Chlorothalonil	1897456	B2	150	500	200	—	—	150
Chlorotoluene, o-	95498	D	—	700	2,000	---		700
Chlorotoluene, p-	106434	D	—	700	2,000	—	—	700
Chlorpyrifos	2921882	D	—	100	30	---		30
Chrysene	218019	B2	—	—	—	0.2 / 0	—	0.2
Cumene (see Isopropylbenzene)								
Cyanazine	21725462	C	—	70	20	— / 1	—	20
2,4-D (2,4-Dichlorophenoxyacetic acid)	94757	D	—	400	100	70 / 70	100	100
Dacthal (DCPA)	1861321	D	—	20,000	5,000	---	---	5,000
Dalapon	75990	D	—	900	300	200 / 200	--	300

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| Chemical ORGANICS | CAS # | Cancer Risk | | Standards and Health Advisories | | | | Superfund |
		Cancer Group	10^{-4} Cancer Risk (µg/L)	DWEL (µg/L)	Longer-term HA (Child) (µg/L)	MCL / MCLG ug/L)	URTH -STAR- Level (µg/L)	Removal Action Level (µg/L)
Di[2-ethylhexyl]adipate	103231	C	3,000	20,000	20,000	400 / 400	—	4,000
Diazinon	333415	E	—	3	5	—	—	3
Dibenzo[a,h]anthracene	53703	B2	—	—	—	0.3 / 0	—	0.3
Dibromoacetonitrile	3252435	C	—	800	2,000	—	—	800
Dibromochloromethane (see Chlorodibromomethane)								
Dibromochloropropane (DBCP)	96128	B2	3	—	—	0.2 / 0	3	3
Dibromomethane (Methylene Bromide)	74953	D	—	—	—	—	—	—
Dibutyl phthalate (Di-n-butyl phthalate)	84742	D	—	4,000	—	—	—	4,000
Dicamba	1918009	D	—	1,000	300	—	—	300
Dichloroacetic acid	79436	B2	—	100	1,000	60^c / 0	—	100
Dichloroacetonitrile	3018120	C	—	300	800	—	—	300
Dichlorobenzene -o (1,2-)	95501	D	—	3,000	9,000	600 / 600	3,000	3,000
Dichlorobenzene -m (1,3-)	541731	D	—	3,000	9,000	600 / 600	—	3,000
Dichlorobenzene -p (1,4-)	106467	C	—	4,000	10,000	75 / 75	750	750
Dichlorodifluoromethane (Freon-12)	75718	D	—	5,000	9,000	—	—	5,000
Dichloroethane (1,1-)	75343	C^a	—	3,500^a	—	—	—	3,500
Dichloroethane (1,2-) (Ethylene dichloride)	107062	B2	40	—	700	5 / 0	40	40
Dichloroethylene (1,1-)	75354	C	—	400	1,000	7 / 7	70	70
Dichloroethylene (cis- 1,2-)	156592	D	—	400	3,000	70 / 70	400	400
Dichloroethylene (trans- 1,2-)	156605	D	—	600	2,000	100 / 100	600	600
Dichloromethane (Methylene chloride)	75092	B2	500	2,000	—	5 / 0	—	500
Dichlorophenol (2,4-)	120832	D	—	100	30	—	—	30
Dichloropropane (1,2-)	78875	B2^a	—	—	—	5 / 0	—	5
Dichloropropene (1,3-) (cis and trans)	542756	B2	20	10	30	— / 0	—	10
Dieldrin	60571	B2	0.2	2	0.5	—	—	0.2
Diethyl phthalate	84662	D	—	30,000	—	—	—	30,000
Diethylhexyl (see Adipates)								

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| Chemical | | Cancer Risk | | Standards and Health Advisories | | | | Superfund |
ORGANICS	CAS #	Cancer Group	10^{-4} Cancer Risk (µg/L)	DWEL (µg/L)	Longer-term HA (Child) (µg/L)	MCL / MCLG (µg/L)	URTH -STAR- Level (µg/L)	Removal Action Level (µg/L)
Diethylhexyl phthalate	117817	B2	300	700	—	6 / 0	—	300
Dimethrin	70382	D	—	10,000	10,000	—	--	10,000
Dimethyl methylphosphonate	756796	C	700	7,000	2,000	—	---	2,000
Dimethyl phthalate	131113	D	—	—	—	—	—	---
DIMP (Diisopropylmethylphosphonate)	1445756	D	—	3,000	8,000	—	---	3,000
Dinitrobenzene (1,3-)	99650	D	—	5	40	—	—	5
Dinitrotoluene (2,4-)	121142	—	—	100	300	—	---	---
Dinitrotoluene (2,6-)	25321146	—	—	40	400	—	—	—
Dinitrotoluene, tg[d] (2,6- & 2,4-)	—	B2	5	—	—	—	—	5
Dinoseb	88857	D	—	40	10	7 / 7	—	10
Dioxane p- (1,4-)	123911	B2	700	—	—	—	---	700
Dioxin (see 2,3,7,8-TCDD)								
Diphenamid	957517	D	—	1,000	300	—	---	300
Diphenylamine	122394	D	—	1,000	300	—	—	300
Diquat	85007	D	—	80	—	20 / 20		80
Disulfoton	298044	E	—	1	3	—	—	1
Dithiane (1,4-)	505293	D	—	400	400	—	---	400
Diuron	330541	D	—	70	300	—	—	70
Endothall	145733	D	—	700	200	100 / 100	—	200
Endrin	72208	D	—	10	3	2 / 2	—	3
Epichlorohydrin	106898	B2	400	70	70	Treat Tech. / 0	70	70
Ethylbenzene	100414	D	—	3,000	1,000	700 / 700	1,000	1,000
Ethylene dibromide (1,2-) (EDB)	106934	B2	0.04	—	—	0.05 / 0	0.05	0.05
Ethylene dichloride (see 1,2-Dichloroethane)								
Ethylene glycol	107211	D	—	40,000	6,000	—	—	6,000
Ethyl ether	60297	—	—	7,000[a]	—	—	—	7,000
Ethylene thiourea (ETU)	96457	B2	30	3	100	—	—	3

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ORGANICS	CAS #	Cancer Group	10^{-4} Cancer Risk (µg/L)	DWEL (µg/L)	Longer-term HA (Child) (µg/L)	MCL / MCLG (µg/L)	URTH -STAR- Level (µg/L)	Removal Action Level (µg/L)
Fenamiphos	22224926	D	—	9	5	—	—	5
Fluometuron	2164172	D	—	400	2,000	—	-	400
Fluorene	86737	D	—	1,400	—	—	---	1,400
Fluorotrichloromethane (Freon-11)	75694	D	—	10,000	3,000	—	—	3,000
Fonofos	944229	D	—	70	20	—	—	20
Formaldehyde	50000	B1	—	5,000	5,000	—	---	5,000
Freon-11 (see Fluorotrichloromethane)								
Freon-12 (see Dichlorodifluoromethane)								
Freon 113 (1,1,2-Trichloro-1,2,2-trifluoroethane)	76131	--	—	1,100,000[a]	—	—	—	1,100,000
Glyphosate	1071836	E	—	4,000	1,000	700 / 700	---	1,000
Heptachlor	76448	B2	0.8	20	5	0.4 / 0	0.8	0.8
Heptachlor epoxide	1024573	B2	0.4	0.4	0.1	0.2 / 0	0.4[c]	0.4
Hexachlorobenzene	118741	B2	2	30	50	1 / 0	—	2
Hexachlorobutadiene	87683	C	—	70	100	— / 1	---	70
Hexachlorocyclohexane, gamma (see Lindane)								
Hexachlorocyclopentadiene	77474	D	—	200	—	50 / 50	—	200
Hexachloroethane	67721	C	—	40	100	—	—	40
Hexane (n-)	110543	D	—	—	4,000	—	---	4,000
Hexazinone	51235042	D	—	1,000	3,000	—	—	1,000
HMX (Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)	2691410	D	—	2,000	5,000	—	—	2,000
Indeno[1,2,3-c,d]pyrene	193395	B2	—	—	—	0.4 / 0	---	0.4
Isophorone	78591	C	4,000	7,000	15,000	—	---	7,000
Isopropyl methylphosphonate	6838933	D	—	4,000	30,000	—	—	4,000
Isopropylbenzene (Cumene)	98828	—	—	1,400[a]	—	—	---	1,400
Kerb (see Pronamide)								
Lindane (Hexachlorocyclohexane, gamma)	58899	C	—	10	30	0.2 / 0.2	2	2

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Chemical ORGANICS	CAS #	Cancer Risk		Standards and Health Advisories				Superfund
		Cancer Group	10^{-4} Cancer Risk (µg/L)	DWEL (µg/L)	Longer-term HA (Child) (µg/L)	MCL / MCLG (µg/L)	URTH -STAR- Level (µg/L)	Removal Action Level (µg/L)
Malathion	121755	D	—	800	200	—	—	200
Maleic hydrazide	123331	D	—	20,000	5,000	—	—	5,000
MCPA (4-Chloro-2-methylphenoxy)-acetic acid	94746	E	—	50	100	—	---	50
Methomyl	16752775	D	—	900	300	—	---	300
Methoxychlor	72435	D	—	200	50	40 / 40	50	50
Methyl bromide (see Bromomethane)								
Methyl chloride (see Chloromethane)								
Methyl ethyl ketone (2-Butanone)	78933	D[a]	—	21,000[a]	—	—	—	21,000
Methyl parathion	298000	D	—	9	30	—	—	9
Methyl tert butyl ether	1634044	D	—	200	500	—	---	200
Methylene bromide (see Dibromomethane)								
Methylene chloride (see Dichloromethane)								
Metolachlor	51218452	C	—	3,500	1,000	—	—	1,000
Metribuzin	21087649	D	—	900	300	—	---	300
Monochloroacetic acid (Chloroacetic acid)	79118	—	—	70[a]	—	—	—	70
Monochlorobenzene (Chlorobenzene)	108907	D	—	700	2,000	100 / 100	700	700
Naphthalene	91203	D	—	100	400	—	—	100
Nitroguanidine	556887	D	—	4,000	10,000	—	-	4,000
Nitrophenols p-	25154556	D	—	300	800	—	—	300
Octachlorocamphene (see Toxaphene)								
Oxamyl	23135220	E	—	900	200	200 / 200	—	200
Paraquat	1910425	E	—	200	50	—	---	50
Pentachloronitrobenzene (PCNB)	82688	C[a]	—	100[a]	—	—	---	100
Pentachlorophenol	87865	B2	30	1,000	300	1 / 0	30	30
Perchloroethylene (see Tetrachloroethylene)								
Phenol	108952	D	—	20,000	6,000	—	---	6,000

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Chemical ORGANICS	CAS #	Cancer Group	10⁻⁴ Cancer Risk (µg/L)	DWEL (µg/L)	Longer-term HA (Child) (µg/L)	MCL / MCLG (µg/L)	URTH -STAR- Level (µg/L)	Superfund Removal Action Level (µg/L)
Picloram	1918021	D	—	2,000	700	500 / 500	—	700
Polychlorinated biphenyls (PCBs)	1336363	B2	0.5	—	—	0.5 / 0	0.5	0.5
Prometon	1610180	D	—	500	200	—	—	200
Pronamide (Kerb)	23950585	C	—	3,000	800	—	—	800
Propachlor	1918167	D	—	500	100	—	—	100
Propazine	139402	C	—	700	500	—	—	500
Propham	122429	D	—	600	5,000	—	—	600
Pyrene	129000	D	—	1,100	—	—	—	1,100
RDX (Hexahydro-1,3,5-trinitro-1,3,5-triazine)	121824	C	30	100	100	—	—	100
Simazine	122349	C	—	200	70	4 / 4	—	40
Styrene	100425	C	—	7,000	2,000	100 / 100	1,000	1,000
T (2,4,5-)	93765	D	—	350	800	—	—	350
Tackle (see Acifluorfen)								
TCDD (2,3,7,8-) (v) (Dioxin)	1746016	B2	0.00002	0.00004	0.00001	0.00003 / 0	—	0.00003
Tebuthiuron	34014181	D	—	2,000	700	—	—	700
Temik (see Aldicarb)								
Terbacil	5902512	E	—	400	300	—	—	300
Terbufos	13071799	D	—	5	1	—	—	1
Tetrachloroethane (1,1,1,2-)	630206	C	100	1,000	900	—	—	900
Tetrachloroethane (1,1,2,2-)	79345	Cª	20ª	—	—	—	—	2
Tetrachloroethylene (Perchloroethylene)	127184	B2ª	70	500	1,000	5 / 0	70	70
Toluene	108883	D	—	7,000	2,000	1,000 / 1,000	—	2,000
Toxaphene (Octachlorocamphene)	8001352	B2	3	3	—	3 / 0	3	3
TP (2,4,5-) (2(2,4,5-Trichlorophenoxy-propionic acid)	93721	D	—	300	70	50 / 50	70	70
Trichloroacetaldehyde (Chloral) see Chloral hydrate (hydrated form of trichloroacetaldehyde)								
Trichloroacetic acid	76039	C	—	4,000	4,000	60ᶜ / 300	—	3,000
Trichlorobenzene (1,2,4-)	120821	D	—	400	100	70 / 70	—	100

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Chemical ORGANICS	CAS #	Cancer Risk		Standards and Health Advisories				Superfund
		Cancer Group	10^{-4} Cancer Risk (µg/L)	DWEL (µg/L)	Longer- term HA (Child) (µg/L)	MCL / MCLG (µg/L)	URTH -STAR- Level (µg/L)	Removal Action Level (µg/L)
Trichlorobenzene (1,3,5-)	108703	D	—	200	600	—	..	200
Trichloroethane (1,1,1-)	71556	D	—	1,000	40,000	200 / 200	1,000	1,000
Trichloroethane (1,1,2-)	79005	C	—	100	400	5 / 3	---	30
Trichloroethylene (Trichloroethene)	79016	B2	300	300	—	5 / 0	300	300
Trichloromethane (see Chloroform)								
Trichlorophenol (2,4,6-)	88062	B2	300	—	—	—	---	300
Trichlorophenoxypropionic acid (2(2,4,5-)) (see 2,4,5-TP)								
Trichloropropane (1,2,3-)	96184	B2	—	200	600	—	---	200
1,1,2-Trichloro-1,2,2-trifluoroethane (see Freon 113)								
Trifluralin	1582098	C	500	300	80	—	—	80
Trinitroglycerol	55630	—	—	—	5	—	—	5
Trinitrotoluene (2,4,6-)	118967	C	100	20	20	—	---	20
Vinyl chloride	75014	A	1.5	—	10	2 / 0	2	2
Vydate (see Oxamyl)								
Xylenes (mixed)	1330207	D	—	60,000	40,000	10,000 / 10,000	40,000	40,000

a Based on data from IRIS or HEAST in the absence of a published U.S. EPA, Office of Water value

b Total for all trihalomethanes combined cannot exceed 80 µg/L

c Total for all haloacetic acids cannot exceed 60 µg/L

d Technical Grade (tg); 2,4- and 2,6-Dinitrotoluene are unlikely to occur alone

e Based on special considerations

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Ammonia	7664417	D	—	—	—	—	—	34,000[a] (taste)
Antimony	7440360	D	—	10	10	6 / 6	—	10
Arsenic	7440382	A	2	—	—	50 / —	—	50
Asbestos fibers >10 µm	1332214	A	700 MFL	—	—	7 MFL / 7 MFL	70 MFL	70 MFL[b]
Barium	7440393	D	—	2,000	—	2,000 / 2,000	—	2,000
Beryllium	7440417	B2	0.8	200	4,000	4 / 4	—	1
Boron	7440428	D	—	3,000	900	—	—	900
Bromate	15541454	—	—	—	—	10 / 0	—	10
Cadmium	7440439	D	—	20	5	5 / 5	5	5
Chloramines (measured free chlorine)	10599903	D[a]	—	3,300	1,000	4,000 / 4,000	—	4,000
Chlorine	7782505	D	—	3,500	—	4,000 / 4,000	—	4,000
Chlorine dioxide	10049044	D	—	350	—	800 / 300	—	800
Chlorite	7758192	D	—	100	—	1,000 / 80	—	1000
Chromium III (see Chromium total)	16065831							
Chromium VI (see Chromium total)	18540299							
Chromium (total)	—	D	—	200	200	100 / 100	200	200
Copper	7440508	D	—	—	—	Treat. T. / 1,300	1,300	1,300
Cyanide	57125	D	—	800	200	200 / 200	—	200
Fluoride	16984488	—	—	4,200	—	4,000 / 4,000	5,000[c]	5,000
Hypochlorite	7681529	—	—	—	—	—/ 4,000	—	—
Hypochlorous acid	7790923	—	—	—	—	— / 4,000	—	—
Lead at tap	7439921	B2	—	—	—	Treat. Tech. / 0	30[c]	30
Manganese	7439965	D[a]	—	200	—	— / —	—	200
Mercury	7439976	D	—	10	—	2 / 2	10	10
Molybdenum	7439987	D	—	200	10	—	—	10
Nickel	7440020	D	—	600	500	100 / 100	—	500
Nitrate	14797558	—	—	56,000	—	10,000 / 10,000	10,000	10,000

NUMERIC REMOVAL ACTION LEVELS FOR CONTAMINATED DRINKING WATER SITES
PRIMARY DRINKING WATER STANDARDS AND HEALTH ADVISORIES
March 1995

Chemical INORGANICS	CAS #	Cancer Risk		Standards and Health Advisories				Superfund
		Cancer Group	10^{-4} Cancer Risk (µg/L)	DWEL (µg/L)	Longer-term HA (Child) (µg/L)	MCL / MCLG (µg/L)	URTH -STAR- Level (µg/L)	Removal Action Level (µg/L)
Nitrite	14797650	—	—	5,600	—	1,000 / 1,000	1,000	1,000
Nitrate+Nitrite	—	—	—	—	—	10,000 / 10,000	10,000	10,000
Selenium	7782492	—	—	200	—	50 / 50	200	200
Silver	7440224	D	—	200	200	—	—	100[d]
Strontium	7440246	D	—	90,000	25,000	—	—	25,000
Sulfate	7757826	—	—	—	—	—	—	250,000 (aesthetics)
Thallium	7440280	—	—	2	7	2 / 0.5	—	2
Vanadium	7440622	D	—	250[a]	—	—	—	250
White phosphorus	772314	D	—	0.5	—	—	—	0.5
Zinc	7440666	D	—	10,000	3,000	—	—	3,000
Zinc chloride (measured as zinc)	—	D	—	10,000	3,000	—	—	3,000

[a] Based on data from IRIS or HEAST in the absence of a published U.S. EPA, Office of Water value

[b] MFL = million fibers per liter

[c] Based on special considerations

[d] Secondary Maximum Contaminant Level intended to protect general public from argyuria (a cosmetic effect) over a lifetime

♻EPA

Draft Soil Screening Level Guidance

NOTICE. This document is draft and should only be used in the context of demonstration pilots being overseen by the U.S. EPA. The methods used to support the approach discussed herein will undergo rigorous technical review and public comment before this document is finalized along with SSLs for approximately 60 additional chemicals in the summer of 1994.

BACKGROUND

On June 19, 1991, the U.S. Environmental Protection Agency's (EPA's) Administrator charged the Office of Solid Waste and Emergency Response (OSWER) with conducting a 30-day study to outline options for accelerating the rate of cleanups at National Priority List (NPL) sites. The study found that the current investigation/remedy selection process takes over 3 years to complete because each site is treated as a unique problem, requiring the preparation of site-specific risk assessments, cleanup levels, and technical solutions. The study proposed that standardizing the remedial planning and remedy selection process would significantly reduce the time it takes to start cleanups and would improve consistency across the Regions. One of the specific proposals was for OSWER to "examine the means to develop standards or guidelines for contaminated soils."

On June 23, 1993, EPA announced the development of Soil Trigger Levels as one of the Administrative Improvements to the Superfund program. This fact sheet presents Soil Screening Levels (SSLs) (formerly known as trigger levels) for 30 chemicals and represents OSWER's first step toward standardizing the evaluation and cleanup of contaminated soils under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA).

An SSL is a chemical concentration in soil that represents a level of contamination above which there is sufficient concern to warrant further site-specific study. Concentrations in soil above this screening level would not automatically designate a site as "dirty," nor trigger a response action. However, they suggest that a further evaluation of the potential risks that may be posed by site contaminants is appropriate. Generally, if contaminant concentrations in soil fall below the screening level and the site meets specific residential use conditions, no further study or action is warranted for that area under CERCLA (Superfund). However, some States have developed screening numbers that are more stringent than those presented in this fact sheet, and therefore further study may be warranted under State programs.

PURPOSE OF SSLs

The primary purpose of the SSLs is to accelerate decision-making concerning contaminated soil. Initial applications will focus remedial investigations by eliminating from further study site areas that do not warrant further study under CERCLA. In fostering prompt identification of the contaminants and exposure areas of concern, the SSLs may also help simplify or accelerate the baseline risk assessment and may serve as Preliminary Remediation Goals (PRGs) under specified conditions. EPA will explore other potential applications as it proceeds to refine and expand this guidance. Such applications may include removal response actions, site assessment/NPL listing, voluntary cleanups, and Resource Conservation and Recovery Act (RCRA) Corrective Actions.

ATTRIBUTES OF SSLs

The 30 SSLs presented in this document have been developed using residential land use human exposure assumptions and considering three pathways of exposure to the contaminant (see Figure 1):

- ingestion of soil

- inhalation of volatiles and fugitive dusts

- migration of contaminants through soil to an underlying potable aquifer.

These pathways have proven to be the most common routes of human exposure to contaminants in the residential setting at hazardous waste sites evaluated by EPA. Also, substantial efforts have been made to model these particular pathways.

Other routes/pathways may contribute significantly to the risk posed by exposure to specific contaminants (e.g., dermal exposure or exposure via food chain contamination). OSWER will continue to seek consensus on the appropriate methods required to quantify additional routes/pathways generically. The results of these efforts may be included in the final guidance.

Figure 1. Pathways addressed by soil screening.

Direct Ingestion of Groundwater and Soil

Inhalation

Air

Blowing Dust and Volatilization

Leaching

Ground-water
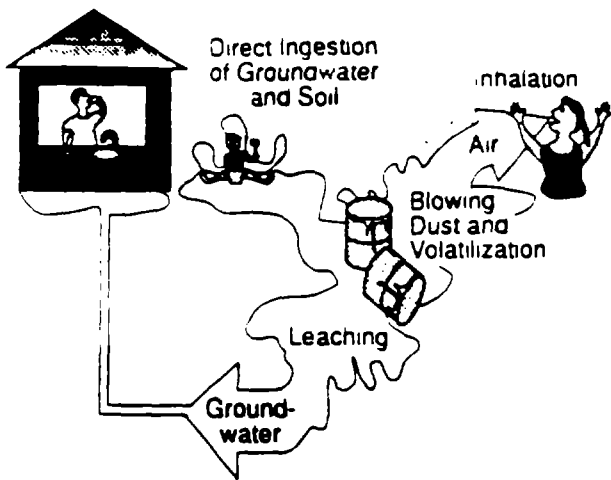
Not Addressed:
- Ecological effects
- Dermal absorption
- Indoor exposure to volatiles from soil and water
- Consumption of fish, beef, or dairy products
- Land uses other than residential

An overview of key SSL attributes includes:

- SSLs calculated for the ingestion and inhalation pathways are based on standard equations modified from the *Human Health Evaluation Manual (Part B)* (U.S. EPA, 1991).

- SSLs for migration to groundwater pathways are based on a partitioning equation coupled with a dilution and attenuation factor (DAF).

- Conservative default values were used to calculate levels protective of "high end" individual exposures.

- SSLs are generally based on a 10^{-6} risk for carcinogens, or a hazard quotient of 1 for noncarcinogens; SSLs for protection of groundwater are based on nonzero maximum contaminant level goals (MCLGs), or maximum contaminant levels (MCLs), if available, or these same risk-based targets otherwise.

- SSLs are calculated for individual exposure pathways.

The SSLs correspond to a 10^{-6} risk level for carcinogens and a hazard quotient of 1 for noncarcinogens and the potential for additive effects has not been "built in" to the SSLs through apportionment. For carcinogens, EPA believes that setting a 10^{-6} risk level for individual chemicals and pathways will generally lead to cumulative risks within the risk range (10^{-4} to 10^{-6}) for the combinations of chemicals typically found at Superfund sites.

For noncarcinogens, there is no widely accepted "risk range." Thus, for developing national numbers, options are either (1) to set the risk level for individual contaminants at the reference

quotient of 1), or (2) to set chemical-specific concentrations by apportioning risk based on some arbitrarily chosen fraction of the acceptable risk level (e.g., one-fifth or one-tenth the RfD/RfC). The Agency believes, and the Science Advisory Board agrees (U.S. EPA, 1993b), that noncancer risks should be added only for those chemicals with the same toxic endpoint or mechanism of action. Because the combination of contaminants will vary from site to site, the potential for additive effects and the need to apportion risk must be a site-specific determination.

Practically speaking, however, the five SSLs listed in Table 1 that are based on noncarcinogenic effects (RfDs) all have different endpoints of toxicity (i.e., the critical effects on which the RfDs are based are different). Thus risks for cumulative exposure would not be additive. Furthermore, for the noncarcinogenic volatiles (e.g., ethylbenzene and toluene), the SSLs based on the ingestion pathway are very high, higher than what is physically possible. In these cases, it is necessary to establish a reasonable "ceiling limit" for the amount of chemical that may be in the soil matrix at sites likely to use this guidance. For the purposes of this guidance, this "ceiling limit" is based on the soil saturation limit (C_{sat}), not toxicity, and serves as the SSL for that chemical. For these reasons, straight apportionment of SSLs in this fact sheet wou' 'e inappropriate.

For the groundwater pathway only, SSLs are part of a four-tiered approach to evaluating soil contaminants that may leach to groundwater. The tiers reflect increasing levels of site specificity and cost but generally decreasing levels of conservatism. The first tier SSLs rely heavily on concentration levels derived from mathematical models and generic assumptions. If contaminant levels at a site do not exceed the first tier SSLs and other site exposure pathways are accounted for in the assumptions used to derive the SSLs, then the area or site is no longer of concern under CERCLA remedial authority. If contaminant levels at a site equal or exceed the first tier SSLs, or other pathways of concern are present, full site investigation may be initiated or one may consider higher tier screening analyses. The other three tiers are distinguished by their approach to evaluating the soil-to-groundwater pathway. Tier 2 uses site-specific values in a partitioning equation, Tier 3 uses a leach test, and Tier 4 involves full-scale site-specific modeling.

LIMITATIONS OF SSLs

SSLs do not trigger the need for response actions or define "unacceptable" levels of contaminants in soil. In addition, the levels are not necessarily protective of all known human exposure pathways, reasonable land uses, or ecological threats.

SSLs were not developed as nationwide cleanup levels or standards. They are risk-based levels that have not yet been modified based on the Superfund remedy selection criteria that are designed to tailor final cleanup levels to site-specific conditions (NCP Section 300.430 (3)(2)(i)(A)).

Chemical	Pathway-specific values for surface soils (mg/kg)		Surface soil SSLs (mg/kg)[b]	Groundwater pathway levels (mg/kg)		
	Ingestion	Inhalation		Unadjusted	With 10 DAF[c]	With 100 DAF[c]
α-BHC	0.1 [d]	1.0 [d]	0.1 [d]	0.0001 [e]	0.001 [d]	0.01 [d]
Benzene	22 [d]	2.5 [d]	2.5 [d]	0.001 [e]	0.01 [d]	0.1
Benzo(a)pyrene	0.11 [d]	13.3 [d]	0.11 [d]	0.71 [d]	7.1	71
Carbon tetrachloride	4.9 [d]	1.5 [d]	1.5 [d]	0.003 [e]	0.03	0.3
Chlordane	0.49 [d]	0.6 [d]	0.49 [d]	0.2 [d]	2	20
Chlorobenzene	1,600 [f]	170 [g]	170 [g]	0.05	0.5	5
Chloroform	100 [d]	1.1 [d]	1.1 [d]	0.02	0.2	2
Chrysene	110 [d]	0.8 [g]	0.8 [g]	0.04	0.4	4
DDT	1.9 [d]	3.9 [d]	1.9 [d]	0.23	2.3	23
1,4-Dichlorobenzene	27 [d]	80 [g]	27 [d]	0.08 [e]	0.8	8
1,1-Dichloroethane	7,800 [f]	450 [g]	450 [g]	0.62	6.2	62
1,1-Dichloroethene	1.1 [d]	0.17 [d]	0.17 [d]	0.002 [e]	0.02	0.2
Dieldrin	0.04 [d]	5.1 [d]	0.04 [d]	0.0001 [e]	0.001 [e]	0.01
Ethylbenzene	7,80C [f]	58 [g]	58 [g]	0.33	3.3	33
Methylene chloride	85 [d]	44 [d]	44 [d]	0.001 [e]	0.007 [e]	0.07
Naphthalene	3,100 [f]	52 [g]	52 [g]	2.5	25	250
PCB-1260	1 [i]	—[h]	—[h]	0.82	8.2	82
Pentachlorophenol	5.3 [d]	—[h]	—[h]	0.001 [e,j]	0.009 [e,j]	0.09 [j]
Tetrachloroethene	12 [d]	41 [d]	12 [d]	0.003 [e]	0.03	0.3
Toluene	16,000 [f]	150 [d]	150 [g]	0.36	3.6	36
1,2,4-Trichlorobenzene	780 [f]	93 [d]	93 [g]	0.23 [e]	2.3	23
1,1,1-Trichloroethane	7,000 [f]	420 [g]	420 [g]	0.07	0.7	7
Trichloroethene	58 [d]	13 [d]	13 [d]	0.001 [e]	0.01 [e]	0.1
Vinyl chloride	0.34 [d]	0.02 [d]	0.02 [d]	0.0002 [e]	0.002 [e]	0.02
Xylenes (mixed)	160,000 [f]	97 [g]	97 [g]	5.7	57	570
Arsenic	0.37 [d]	2,600 [d]	0.37 [d]	1.4 [i]	14 [i]	140 [i]
Cadmium	39 [f]	6,200 [d]	39 [f]	0.81 [i]	8.1 [i]	81 [i]
Chromium (VI)	390 [f]	930 [d]	390 [f]	1.9 [i]	19 [i]	190 [i]
Mercury	23 [f]	41 [f]	23 [i]	0.3 [i]	3 [i]	30 [i]
Nickel	1,600 [f]	47,000 [d]	1,600 [f]	8.2 [i]	82 [i]	820 [i]

[a] Screening Levels based on human health criteria only.
[b] Surface soil SSLs represent the lower of ingestion and inhalation values.
[c] DAF = Dilution and attenuation factor.
[d] Calculated values correspond to a cancer risk level of 1 in 1,000,000.
[e] Level is at or below Contract Laboratory Program required quantitation limit for Regular Analytical Services (RAS).
[f] Calculated values correspond to a noncancer hazard quotient of 1.
[g] Soil saturation concentration (C_{sat}).
[h] No toxicity criteria available for that route of exposure.
[i] A preliminary remediation goal of 1 ppm has been set for PCBs based on *Guidance on Remedial Actions for Superfund Sites with PCB Contamination* (U.S. EPA, 1990) and on Agency-wide efforts to manage PCB contamination.
[j] SSLs for pH of 6.8.

However. SSLs can serve as PRGs in the following cases:

- Where site conditions mimic the model assumptions underlying the SSLs (i.e., all pathways of concern at a given site match those accounted for in the SSLs), or

- Where the site manager or owner decides not to incur costs of additional site-specific study to arrive at less conservative but still protective levels.

The primary condition for use of the SSLs is that exposure pathways of concern and site conditions must match those taken into account by the levels. Thus, at all sites it will be necessary to develop a simple conceptual site model to identify likely source areas, exposure pathways, and potential receptors to assist in determining the extent to which the SSLs can serve as PRGs. In addition to developing a conceptual site model.

In accordance with the National Contingency Plan (NCP), the decisionmaker will need to consider a variety of factors in determining whether any modification of the SSLs (PRGs) is appropriate in setting final cleanup levels (NCP Section 300.430(e)(2)(i)(A)). Ultimately, final cleanup levels are set through the evaluation of the NCP's nine criteria, including cost, long-term effectiveness, and implementability. If groundwater is the driving pathway, even at this final stage, the option exists to consider other SSL tiers in identifying final cleanup levels.

TECHNICAL BACKGROUND

The models and assumptions used to develop the SSLs construct scenarios representative of a "reasonable maximum exposure" (RME) in the residential setting. U.S. EPA (1989b) outlined the Superfund program's approach to calculating an RME. Since that time, the EPA (U.S. EPA, 1991) has coined a new term that corresponds to the definition of RME: "high-end individual exposure." The Superfund program's method to estimate the high-end (outlined in U.S. EPA, 1989b) is to combine an arithmetic average value for site concentration with high-end values for intake and duration. The estimate of high-end exposure is then compared to chemical-specific Agency toxicity criteria found in the Integrated Risk Information System (IRIS) and Health Effects Assessment Summary Tables (HEAST). The method used to set SSLs combines high-end default values for the intake and duration parameters with Agency toxicity criteria to back-calculate to a screening level in soil. Therefore, attainment of SSLs should be measured based on an arithmetic average.

Although the generic assumptions are not considered overly conservative, EPA recognizes that site-specific conditions may differ significantly from the generic assumptions used in the models. Therefore, for the groundwater pathway the subsequent tiers of the SSLs allow for the substitution of some of the generic fate and transport assumptions with site-specific data to derive alternative "screening levels" that are more site-specific. Bear in mind, however, that one purpose of the SSLs is to define a level in soil below which no further study or action would be required. Therefore, alternative levels using site-specific data, although less conservative, must still be protective of "high-end" individual exposures.

The following sections present the equations and generic assumptions used to calculate the Screening Levels for each pathway evaluated.

Direct Ingestion

Agency toxicity criteria for noncarcinogens establish a level of "daily" exposure that is not expected to cause deleterious effects over a lifetime of exposure (i.e., 70 years). Depending on the contaminant, however, exceeding the RfD (i.e., the "acceptable" daily level) for a short period of time may be cause for concern. For example, if there is reason to believe that exposure to soil may be higher at a particular stage of an individual's lifetime, one would want to protect for that shorter

period of high exposure. Because a number of studies have shown that inadvertent ingestion of soil is common among children age 6 and younger (Calabrese et al., 1989; Davis et al., 1990; Van Wijnen et al., 1990), OERR set SSLs at concentrations that are protective of this increased exposure during childhood by ensuring that the chronic Reference Dose (or RfC) is not exceeded during this shorter (6-year) time period (Equation 1). If there is reason to believe that exposures at a site may be significant over a short period of time (e.g., extensive soil excavation work in a dry region), depending on the contaminant, the site manager should consider the potential for acute health effects as well.

Equation 1: Screening Level Equation for Ingestion of Noncarcinogenic Contaminants in Residential Soil

$$\text{Screening Level (mg/kg)} = \frac{\text{THQ} \times \text{BW} \times \text{AT} \times 365 \text{ d/yr}}{1/\text{RfD}_o \times 10^{-6} \text{ kg/mg} \times \text{EF} \times \text{ED} \times \text{IR}}$$

Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
RfD$_o$ /oral reference dose (mg/kg-d)	Chemical-specific
BW/body weight (kg)	15
AT/averaging time (yr)	6[a]
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	6
IR/soil ingestion rate (mg/d)[2]	200

[a] For noncarcinogens, Averaging Time is equal to Exposure Duration.

For carcinogens, both the magnitude and duration of exposure are important. Duration is critical because the toxicity criteria are based on "lifetime average daily dose." Therefore, the total dose received, whether it be over 5 years or 50 years, is averaged over a lifetime of 70 years. To be protective of exposures to carcinogens in the residential setting, OE focuses on exposures to individuals who may live in the same residence for a "high-end" period of time (i.e., 30 years). As mentioned previously, exposure to soil is higher during childhood and decreases with age. Thus, Equation 2 uses a time-weighted average soil ingestion rate for children and adults. The derivation of this time-weighted average is presented in U.S. EPA (1991).

Inhalation of Volatiles and Fugitive Dusts

Agency toxicity criteria indicate that risks from exposure to some chemicals via inhalation far outweigh the risks via ingestion; therefore, the SSLs have been designed to address this pathway. The models and assumptions used to calculate SSLs for inhalation of volatiles and fugitive dusts are updates of the equations presented in U.S. EPA's HHEM Part B guidance (U.S. EPA, 1991) and are presented in Equations 3

- Are there potential ecological concerns?

- Is there potential for land use other than residential?

- Are there other likely human exposure pathways that were not considered in development of the SSLs (e.g., local fish consumption; raising of beef, dairy, or other livestock)?

- Are there unusual site conditions (e.g., unusually large area of contamination, unusually high fugitive dust levels)?

If any of these four conditions exist, then SSLs cannot be used to screen out sites or portions of sites from further evaluation. In addition, SSLs should not be viewed independently of either natural or anthropogenic background concentrations. Where natural background levels are higher than SSLs, generally the SSLs will be of little value since it is inappropriate to conduct further study or action to address contaminants below background. Similarly, when anthropogenic background levels exceed the SSLs, EPA does not encourage additional study or action without first attempting to coordinate such action with the authority responsible for managing the more broadly contaminated area. In either case, the collection of site-specific data is highly recommended.

HOW TO USE SSLs

Table 1 contains SSLs for 30 chemicals. The first column to the right of the chemical name presents values based on soil ingestion. The second column presents the lower of two values derived to protect for either inhalation of volatiles or soil particulates. The third column simply presents the lowest number of the first two columns and may be used as the SSL for surface soils under most residential circumstances. For sites where groundwater is a pathway of concern, SSL values for the migration to the groundwater pathway apply. Three different SSLs address migration of contaminants to groundwater; the selection of an appropriate SSL for this pathway depends on site-specific conditions as discussed below. The first column of groundwater values reflects the levels calculated by the partitioning equation with no correction factor added for dilution and attenuation in the subsurface (unadjusted). The next two columns reflect the levels adjusted by factors of 10 and 100, respectively (10 and 100 DAF), to account for such dilution and attenuation.

As mentioned above, the first step in applying the SSL guidance is to develop a simple conceptual model of the site based on available site sampling data, historical records, aerial photographs, and site hydrogeologic information. This model will establish a hypothesis about the possible contaminant sources, their fate and transport, potential exposure pathways, and human or environmental receptors. If the conceptual model indicates that potential exposure pathways and receptors are fully accounted for in the SSL methodology, the SSLs may be directly applied to the site. However, if the model indicates that the site is either very large or complex or that there are exposure pathways NOT accounted for in the SSL

site. They can be used, however, in the site evaluation since SSLs have been derived on a pathway-specific basis, and, thus, it will only be necessary to evaluate those exposure pathways that are not already considered in the SSL methodology.

The second step involves collecting a representative sample set for each exposure area. (See Measuring Soil Levels for more detailed guidance on sample numbers and locations.) An exposure area is defined as that geographic area in which an individual may be exposed to contamination regularly. It may involve the entire site, portions of a site, or a simple residential lot. To maximize efficiency, data collection should be coordinated with other early sampling efforts that may be undertaken to gain a better understanding of basic site hydrogeology, ecological threats, or the potential for application of various treatment technologies. For example, the decision may be made early on to collect data for site-specific modeling purposes at a particular site; in this case, the site manager should work to limit total trips to the site and minimize the number of samples collected and their locations.

The third step is to compare site-specific data with the SSLs in Table 1. At this point, it is reasonable to revisit the original conceptual site model with the actual site data in hand to reconfirm their accuracy. Generally, this comparison will result in one of three outcomes:

1. Site-measured values indicate that an area falls well below any SSL in the table. These areas of the site can be eliminated from further evaluation.

2. Site-measured data indicate that one or more SSLs have clearly been exceeded by a wide margin. In this case, the SSLs have helped to identify contaminants and exposure pathways of concern on which to focus further analysis or data gathering efforts.

3. A site-measured value exceeds one pathway-specific value but not the others. In this case it is reasonable to focus additional site-specific data collection efforts only on data that will help determine whether there is truly a risk from that pathway at the site. When an exceedance is marginally significant, a closer look at site-specific conditions and exposures may result in the area being eliminated from further study. If this is the case for the groundwater pathway, a manager may choose to collect data specified in the next higher tier(s).

For an NPL site at which SSLs are exceeded, a quick analysis can determine whether the cumulative risks posed by the site exceed the 10^{-4} risk level for carcinogens (or hazard index [HI] of 1 for noncarcinogens), which generally is the trigger for remedial action under Superfund. Where the basis for response action exists, and exposure pathways of concern are addressed by the SSLs, the SSLs become PRGs as defined in the *Human Health Evaluation Manual, Part B* (U.S. EPA 1991).

Equation 2: Screening Level Equation for Ingestion of Carcinogenic Contaminants in Residential Soil

$$\text{Screening Level (mg/kg)} = \frac{TR \times AT \times 365 \text{ d/yr}}{SF_o \times 10^{-6} \text{ kg/mg} \times EF \times IF_{soil/adj}}$$

Parameter/Definition (units)	Default
TR/target cancer risk (unitless)	10^{-6}
SF_o/oral slope factor (mg/kg-d)$^{-1}$	Chemical-specific
AT/averaging time (yr)	70
EF/exposure frequency (d/yr)	350
$IF_{soil/adj}$/age-adjusted soil ingestion factor (mg-yr/kg-d)	114

Equation 3: Screening Level Equation for Inhalation of Carcinogenic Contaminants in Residential Soil

$$\text{Screening Level (mg/kg)} = \frac{TR \times AT \times 365 \text{ d/yr}}{URF \times 1000 \text{ μg/mg} \times EF \times ED \times \left[\frac{1}{VF} + \frac{1}{PEF}\right]}$$

Parameter/Definition (units)	Default
TR/target cancer risk (unitless)	10^{-6}
URF/inhalation unit risk factor (μg/m^3)$^{-1}$	Chemical-specific
AT/averaging time (yr)	70
EF/exposure frequency (d)	350
ED/exposure duration (yr)	30
VF/soil-to-air volatilization factor (m^3/kg)	Chemical-specific
PEF/particulate emission factor (m^3/kg)	4.51×10^9

through 7. The volatilization factor (VF), soil saturation limit (C_{sat}), and dispersion model have all been revised.

Another change from the Part B methodology is the separation of the ingestion and inhalation pathways. Agency toxicity criteria for oral exposures are presented as internal doses in units of mg/kg-d; whereas, the inhalation criteria are presented as concentrations in air (μg/m^3 or mg/m^3) that require conversion to an estimate of internal dose to be comparable to the oral route. EPA's Office of Research and Development (ORD) now believes that the conversion from concentration in air to internal dose is not always appropriate and suggests evaluating these exposure routes separately.

As explained in Part B, the basic principle of the volatilization model is applicable only if the soil concentration is at or below soil saturation. Thus, for those compounds for which the SSL exceeds the soil saturation limit (C_{sat}), the SSL is set at C_{sat}.

Equation 4: Screening Level Equation for Inhalation of Noncarcinogenic Contaminants in Residential Soil

$$\text{Screening Level (mg/kg)} = \frac{THQ \times AT \times 365 \text{ d/yr}}{EF \times ED \times \left[\frac{1}{RfC} \times \left(\frac{1}{VF} + \frac{1}{PEF}\right)\right]}$$

Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
AT/averaging time (yr)	30
EF/exposure frequency (d)	350
ED/exposure duration (yr)	30
RfC/inhalation reference concentration (mg/m^3)	Chemical-specific
VF/soil-to-air volatilization factor (m^3/kg)	Chemical-specific
PEF/particulate emission factor (m^3/kg)	4.7×10^9

Equation 5: Derivation of the Volatilization Fa

$$VF \text{ (m}^3\text{/kg)} = (Q/C) \times \frac{(3.14 \times \alpha \times T)^{1/2}}{(2 \times D_{ei} \times P_a \times K_{as})} \times 10^{-4} \text{ m}^2\text{/cm}^2$$

where:

$$\alpha = \frac{D_{ei} \times P_a}{P_a + (\rho_s)(1 - P_a)/K_{as}}$$

Parameter/Definition (units)	Default
VF/volatilization factor (m^3/kg)	—
(Q/C)/inverse of the mean conc. at the center of a 0.5-acre square source (g/m^2-s per kg/m^3)	101.8
D_{ei}/effective diffusivity (cm^2/s)	$D_i(P_a^{3.33}/P_t^2)$
P_a/air filled soil porosity (unitless)	P_t-θβ
P_t/total soil porosity (unitless)	1-(β/ρ_s)
θ/soil moisture content (cm^3-water/g-soil)	10% or 0.1
β/soil bulk density (g/cm^3)	1.5
ρ_s/true soil density or particle density (g/cm^3)	2.65
K_{as}/soil-air partition coefficient (g-soil/cm^3-air)	(H/K_d) × 41 (41 is a conversion factor)
T/exposure interval (s)	7.9×10^8 s
D_i/diffusivity in air (cm^2/s)	Chemical-specific
H/Henry's law constant (atm-m^3/mol)	Chemical-specific
K_d/soil-water partition coefficient (cm^3/g)	K_{oc} × OC
K_{oc}/organic carbon partition coefficient (cm^3/g)	Chemical-specific
OC/organic carbon content of soil (fraction)	2% or 0.02

Equation 6: Derivation of the Soil Saturation Limit

$$C_{sat} = \frac{(K_d \times C_w \times \beta) + (C_w \times P_w) + (C_w \times H' \times P_a)}{\beta}$$

Parameter/Definition (units)	Default
C_{sat}/soil saturation concentration (mg/kg)	--
K_d/soil-water partition coefficient (L/kg)	K_{oc} x OC
K_{oc}/organic carbon partition coefficient (L/kg)	Chemical-specific
OC/organic carbon content of soil (fraction)	2% or 0.02
C_w/upper-limit of free moisture in soil (mg/L-water)	$S \times \Theta_m$
Θ_m/soil moisture content (kg-water/kg-soil)	10% or 0.1
S/solubility in water (mg/L-water)	Chemical-specific
β/soil bulk density (kg/L)	1.5
P_w/water-filled soil porosity (unitless)	$P_t - P_a$
H'/Henry's law constant (unitless)	H x 41, where 41 is a conversion factor
H/Henry's law constant (atm-m³/mol)	Chemical-specific
P_a/air-filled soil porosity (unitless)	$P_t - \Theta\beta$
Θ/soil moisture content (L-water/kg soil)	10% or 0.1
P_t/total soil porosity (unitless)	$1 - (\beta/\rho_s)$
ρ_s/true soil density or particle density (kg/L)	2.65

Equation 7: Derivation of the Particulate Emission Factor

$$PEF(m^3/kg) = (Q/C) \times \frac{3600 s/h}{0.036 \times (1-G) \times (U_m/U_t)^3 \times F(x)}$$

Parameter/Definition (units)	Default
PEF/particulate emission factor (m³/kg)	4.7×10^9
(Q/C)/inverse of the mean conc. at the center of a 0.5-acre, square source (g/m²-s per kg/m³)	101.8
0.036/respirable fraction (g/m²-h)	0.036
G/fraction of vegetative cover (unitless)	0
U_m/mean annual wind speed (m/s)	4.5
U_t/equivalent threshold value of wind speed at 10 m (m/s)	12.8
F(x)/function dependent on U_m/U_t derived using Cowherd (1985) (unitless)	0.0497

The particulate emission factor (PEF) derived by using the default values in Equation 7 is approximately 0.2 ug/m³. This represents an annual average emission rate estimate that is not appropriate for estimating acute effects. Over the next few months, OSWER will be investigating the impact of acute exposure estimates on the SSLs.

Migration to Groundwater

The methodology for addressing potential contamination of groundwater from contaminants in soil reflects the complex nature of contaminant fate and transport in the subsurface. SSLs for migration to groundwater are based on a tiered approach (see Figure 2). Tier 1 SSLs (presented in Table 1) are based on the commonly used linear form of the Freundlich partitioning equation that describes the ability of contaminants to sorb to organic carbon in soil (Dragun, 1988). Equation 8 incorporates the linear Freundlich equation, along with an adjustment to relate sorbed concentration in soil to the analytically measured total soil concentration.
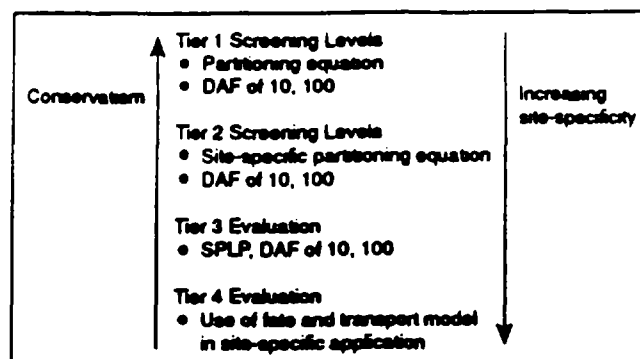
Figure 2. Tiered approach groundwater pathway.

Equation 8: Soil Screening Level Partitioning Equation for Migration to Groundwater

$$\text{Screening Level in Soil (mg/kg)} = C_w [(K_{oc} \times f_{oc}) + (\Theta \times S/BD)]$$

Parameter/Definition (units)	Default
C_w/acceptable groundwater limit (mg/L)	MCL
K_{oc}/organic carbon partitioning coefficient (L/kg)	Chemical-specific
f_{oc}/fraction of organic carbon in soil (unitless)	0.002
Θ/soil porosity (L_{pore}/L_{soil})	0.5
S/fraction water content (L_{water}/L_{pore})	0.3
BD/soil bulk density (kg/L_{soil})	1.5

In this equation, nonzero groundwater MCLGs were used as the acceptable groundwater limits for each contaminant. For the 30 SSLs presented in this guidance, generally the nonzero

MCLs were the same as the MCLs. a noncancer noncancer....

not available. MCLs were used, and. if MCLs were not available. risk-specific concentrations were derived using Agency toxicity criteria. a target cancer risk of 10⁻⁶, and/or a noncancer Hazard Quotient of 1. Default values obtained from U.S. EPA's ORD Laboratory in Athens. Georgia, are used for soil porosity. fraction water content. and bulk density (U.S. EPA. 1985). The soil organic carbon content value of 0.002 used for calculating the SSLs was selected from information on the distribution of this parameter in U.S. soils (Carsel et al.. 1988). The value used for the organic carbon partitioning coefficient (K_{oc}) is the geometric mean of measured values reported in the literature (from a comprehensive literature search [Truesdale, 1992]). For inorganic constituents, the EPA MINTEQ2 chemical speciation model was used to calculate K_d values, which were then used in Equation 8 in place of the K_{oc} x f_{oc} parameters. K_d values for metals are significantly affected by a variety of soil conditions, the most significant of which is pH. For this reason, metal K_d values for three pH conditions were used to develop the SSLs: 4.9, 6.8. and 8.0. Table 1 contains SSLs for inorganics corresponding to a pH of 6.8. Table 2 contains inorganic SSLs corresponding to pH values of 4.9 and 8.0. If pH conditions at a site are not known, the SSL corresponding to a pH of 6.8 should be used. Table 2 also includes SSLs for pentachlorophenol (PCP), whose partitioning behavior is also highly pH dependent.

The partitioning equation relates contaminant concentrations in soil adsorbed to soil organic carbon to soil leachate contaminant concentrations in the unsaturated zone. Contaminant migration through the unsaturated zone to the water table generally reduces the soil leachate concentration by attenuation processes such as adsorption and degradation. Groundwater transport in the saturated zone further reduces concentrations through attenuation and dilution. Generally, to account for those mechanisms in the subsurface environment, a correction factor should be applied to the partitioning equation value. Use of the EPA's Composite Model for leachate migration with Transformation Products (EPACMTP) (U.S. EPA. 1993a) has identified a DAF of 10 as an

value in most cases. However. there are specific circumstances under which use of a DAF is not recommended. such as in areas of very shallow groundwater or karst topography. Likewise. there are other circumstances in which a higher DAF may be appropriate. Further discussion of these situations as well as details on the EPACMTP model are included on the next page of this fact sheet.

The assumptions factored into the Tier 1 levels are conservative. rendering the SSLs fairly stringent. If site concentrations do not exceed the SSLs multiplied by the appropriate DAF. then the pathway is excluded from further investigation. However, if site concentrations do exceed the Tier 1 SSLs, they may be used as PRGs (when appropriate). or a Tier 2, 3, or 4 investigation may be conducted. Each tier requires more site-specific information but may lead to a less stringent "screening" concentration.

The Tier 2 levels represent a minimal increase in site-specificity and perhaps less conservative Screening Levels. The partitioning equation used in the Tier 1 calculation (Equation 8) remains as the base for the Tier 2 levels along with the same DAF (either 1, 10, or 100). However. site-measured values of organic carbon, soil porosity, fraction content. and soil bulk density are substituted into the equation to calculate Screening Levels more tailored to site characteristics. If site concentrations do not exceed the Tier 2 SSLs, then the pathway is excluded from further investigation or concern. The rationale behind this decision is that, because Tier 2 incorporates site-specific information, the levels are more representative of actual site conditions than Tier 1. If site concentrations exceed the Tier 2 SSLs, the user has the option of conducting a Tier 3 or 4 investigation, realizing the increase in site-specificity and cost associated with collecting additional site data.

The Tier 3 investigation involves conducting a specific leach test, the Synthetic Precipitation Leaching Procedure (SPLP) (U.S. EPA, 1992c). If the leach test results divided by the

Table 2. Proposed Groundwater Pathway SSLs for Inorganics and Pentachlorophenol, as a Function of pH[a]

		Proposed groundwater pathway SSLs (mg/kg)					
		Unadjusted		With 10 DAF[b]		With 100 DAF[b]	
Chemical	pH	4.9	8.0	4.9	8.0	4.9	8.0
Arsenic		1.2	1.6	12.5	15.7	125	157
Cadmium		0.06	10.0	0.08	100	0.81	1,001
Chromium (VI)		0.1	1.4	31.4	13.6	314	136
Mercury		0.0002	0.42	0.002	4.2	0.02	42.2
Nickel		0.32	15.7	3.2	157	31.7	1,573
Pentachlorophenol		0.017	0.0009[c]	0.17	0.009[c]	1.7	0.09

[a]Screening Levels based on human health criteria only.
[b]DAF = Dilution:attenuation factor.
[c]Level at or below Contract Laboratory Program required quantitation limit for Regular Analytical Services (RAS).

DAF of 10 exceed the acceptable groundwater limit (e.g., nonzero MCLG. MCL. 10^{-6} risk-based values), then further investigation would be warranted. The SPLP may not be applicable to all contaminated soils (e.g., oily types of waste do not yield suitable results). Therefore the user is advised to use discretion when applying the SPLP. Additional guidance on the use and limitations of the SPLP will be provided in the final guidance.

Tier 4 represents the highest level of site-specificity in evaluating the migration to groundwater pathway. In this investigation, site-specific data are collected and used in a fate and transport model to confirm the threat to groundwater and further determine site-specific cleanup goals as would typically be done for the remedial investigation/feasibility study (RI/FS). A DAF is not used in this tier because the model would account for fate and transport mechanisms in the subsurface. The advantage of this approach is that it accounts for site hydrogeologic, climatologic, and contaminant source characteristics and may result in fully protective but less stringent remediation goals. However, the additional cost of collecting the data required to apply the model should be factored into the decision to conduct a Tier 4 investigation. An evaluation of 10 fate and transport models for potential use in the Tier 4 evaluation will be included in the technical background document for this fact sheet scheduled to be issued by OERR by January of 1994.

The tiered framework for migration to groundwater represents a sliding scale of increasing site-specificity and decreasing conservatism. The assumptions factored into the Tier 1 SSLs are conservative and therefore result in fairly stringent levels that may not be appropriate in all situations. However, the framework allows the user the flexibility to move away from this conservative level by incorporating increasing levels of site empirical data. In this way, site managers or owners of small, relatively uncomplicated sites may benefit from the Tier 1 levels by bypassing the additional costs associated with collecting additional data to conduct further investigations. However, it is likely to be in the interest of site managers or owners of large and complex sites to conduct a more site-specific investigation to develop remediation goals that are more tailored to site-specific conditions.

DETERMINING THE DILUTION/ ATTENUATION FACTOR

For wastes disposed of on land, the leaching of contaminants into the subsurface and subsequent migration into and through groundwater typically constitute a very significant pathway for human and environmental exposure. As contaminants move through the soil and groundwater, they are subjected to a number of physical, chemical, and biological processes that affect the eventual contaminant concentration level at receptor points. These processes include, but are not limited to, attenuation due to sorption of contaminants onto soil and aquifer grains, chemical transformation (e.g., hydrolysis, redox reactions, precipitation), biological degradation, and dilution due to mixing of the leachate from the disposal unit with

ambient groundwater. The contaminant concentration arriving at a receptor point is therefore generally lower than the original contaminant concentration in the leachate leaving the site.

The reduction in concentration can be expressed succinctly by the DAF, defined as the ratio of original leachate concentration to the receptor point concentration. The lowest possible value of DAF is therefore 1, corresponding to the situation where there is no dilution or attenuation of a contaminant at all; i.e., the concentration at the receptor point is the same as that in the leachate as it leaves the waste site. High DAF values on the other hand correspond to a high degree of dilution and attenuation of the contaminant from the leachate to the receptor point.

The Agency has developed subsurface fate and transport models to assess the impact on groundwater quality due to migration of contaminants from wastes on land. Specifically, these models predict the DAF for a potential site of a domestic drinking water receptor well, which may withdraw water from the saturated zone under, or downgradient of, a contaminated area. The model used to develop DAFs for this guidance is the EPACMTP, which consists of three main modules:

1. An unsaturated zone flow and contaminant fate and transport module

2. A saturated zone groundwater flow and contaminant fate and transport module

3. A Monte Carlo driver module, which generates model parameters from nationwide probability distributions.

The unsaturated and saturated zone modules simulate the migration of contaminants from the base of a land disposal unit to a downgradient receptor well. The Agency has extensively verified both the unsaturated and saturated zone modules against other available analytical and numerical models to ensure accuracy and efficiency. Both the unsaturated zone and the saturated zone modules of the EPACMTP, used for the calculation of DAFs for the SSLs, have been reviewed by the EPA Science Advisory Board and found to be suitable for generic applications such as the derivation of nationwide DAFs.

Modeling Procedure

For nationwide Monte Carlo model applications, the input to the model is in the form of probability distributions of each of the model input parameters. The output from the model consists of the probability distribution of DAF values, representing the likelihood that any specific DAF value is exceeded.

For each model input parameter, a probability distribution is provided, describing the nationwide likelihood that the parameter has a certain value. The parameters are divided into four main groups:

1. Source-specific parameters, e.g., area of the waste unit, infiltration rate

2. Chemical-specific parameters, e.g., hydrolysis constants, organic carbon partition coefficient

3. Unsaturated zone-specific parameters, e.g., depth to water table, soil hydraulic conductivity

4. Saturated zone-specific parameters, e.g., saturated zone thickness, ambient groundwater flow rate, location of nearest receptor well.

During the Monte Carlo simulation, values for each model parameter are randomly drawn from their respective probability distributions. In the calculation of the DAFs for the SSLs, site data from over 1,300 sites were used to define parameter ranges and distributions. Each combination of randomly drawn parameter values represents one out of a practically infinite universe of possible waste sites. The fate and transport modules are executed for the specific set of model parameters, yielding a corresponding DAF value. This procedure is repeated, typically on the order of several thousand times, to ensure that the entire universe of possible parameter combinations (waste sites) is adequately sampled. At the conclusion of the analysis, a cumulative frequency distribution of DAF values is constructed and plotted.

The Agency performed a number of sensitivity analyses consisting of fixing one parameter at a time to determine the parameter(s) that have the greatest impact on DAFs. The results of the sensitivity analyses indicate that the climate (net precipitation), soil types, and size of the contaminated area have the greatest effect on the DAFs. The Agency feels that the size of the contaminated area lends itself most readily to practical application of the SSLs.

To calculate the DAF for the SSLs, the drinking water well was located 25 feet downgradient of the edge of the contaminated area, and the location of the intake point (receptor well screen) was assumed to vary within the boundaries of 15 and 300 feet within the aquifer (these values are based on empirical data reflecting a national sample distribution of depth of residential drinking water wells). The sensitivity analyses indicated that the placement of the well 25 feet downgradient of the contaminated area is more conservative than allowing the well to be located directly beneath the contaminated area. The location of the intake point allows for mixing within the aquifer. OSWER believes that this is a reasonable assumption because there will always be some dilution attributed to the pumping of water for residential use from an aquifer. The placement of the well was assumed to vary uniformly within the boundary of the plume. Figure 3 shows a schematic of the compliance point location. From these analyses, the largest allowable areas corresponding to DAFs of 10 and 100 at the 90th percentile protection level are approximately 10 and 1 acre, respectively. Therefore, for sites of up to 10 acres, a DAF of 10 should be applied to the unadjusted SSLs, while for sites at or below 1 acre, a DAF of 100 should be applied to the unadjusted SSLs. If a 95th percentile protectiveness level is used, a DAF of 10 is
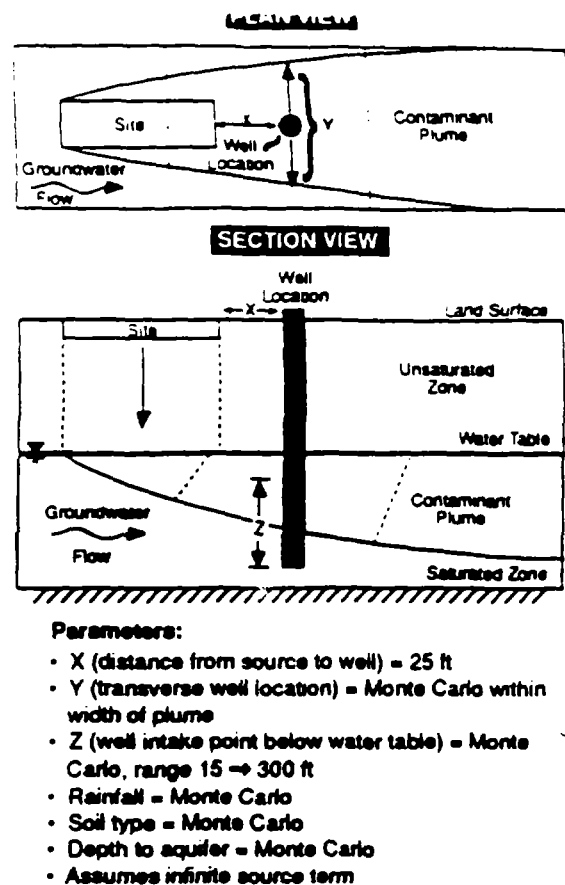

SECTION VIEW

Parameters:

- X (distance from source to well) = 25 ft
- Y (transverse well location) = Monte Carlo within width of plume
- Z (well intake point below water table) = Monte Carlo, range 15 → 300 ft
- Rainfall = Monte Carlo
- Soil type = Monte Carlo
- Depth to aquifer = Monte Carlo
- Assumes infinite source term

Figure 3. Soil to groundwater pathway— calculating the DAF.

protective for areas under 1/2 acre and a DAF of 100 is protective for areas less than 1/10 acre. OSWER is considering whether the 90th or 95th percentile protectiveness level should be used in the final guidance. When sites are located in areas of unusually shallow water table, within 5 feet of surface, the unadjusted SSLs should be used. In this scenario, contamination is located in or directly abo ve saturated zone; therefore, any dilution and attenuation processes within the unsaturated zone would be negligible.

MEASURING SOIL LEVELS

As described in U.S. EPA (1992b), exposure to site contaminants over a long (chronic) period of time is best represented by an arithmetic average concentration; therefore, attainment of the SSLs should be based on the arithmetic mean concentration as well. The issue then becomes the number of samples required to adequately estimate the mean and the area over which the sample concentrations should be averaged. Studies by EPA's Exposure Assessment Group in ORI indicate that 20 to 30 samples per exposure area are needed to calculate an upper confidence limit (UCL_{95}) on the arithmetic mean that is very close to the true mean (U.S. EPA, 1992b); i.e., to adequately estimate the true mean without underestimating it. An appropriate exposure/averaging area can vary i

size, depending on site-specific conditions. At some sites, this may be the entire site; at others, this may be only a portion of the site. For the purposes of this guidance, the Agency believes that the size of a typical residential lot (1/4 acre) is an appropriate averaging area for the most conservative case (i.e., residential land use). For large sites that could be divided into many areas equivalent to the size of a residential lot, the number of samples needed to characterize the site becomes quite high. This, coupled with the costs of analytical services for each sample, could make the sampling costs onerous. Therefore, OERR recommends following guidance for measuring soil contaminant levels at NPL sites.

Sample Pattern

A grid pattern such as a triangular or square/rectangular grid is recommended to establish sample locations for each exposure area (U.S. EPA, 1987). Biased sampling must also be used in areas of suspected contamination or stained soils and must be evaluated separately from the samples obtained by systematic sampling.

Number of Samples

As mentioned, it is necessary to balance the need to achieve statistical confidence in determining a meaningful arithmetic mean concentration of contaminants in each exposure area with the cost of obtaining the 20 to 30 samples recommended by ORD. Compositing of discrete samples is an option since EPA is interested in determining the arithmetic mean of the contaminant concentration(s). Twenty discrete samples can be composited down to four or five composite samples, while maintaining confidence that the area average is not grossly underestimated. Compositing may mask contaminant levels that are slightly higher than the SSL, but areas of high contamination will still be detected. Compositing is both a reasonable approach and an efficient use of resources, since Superfund is interested in average exposure over time. However, none of the composite samples should exceed the prescribed SSL for any contaminant. For volatile organic compounds (VOCs), compositing is not appropriate (U.S. EPA, 1989a, 1992a). Therefore, OERR advocates that 10 discrete samples should be taken per exposure area for VOCs, and no sample can exceed the Screening Level(s). Both the discrete VOC samples and the composites must be analyzed by Contract Laboratory Program (CLP) (or equivalent) methods. (NOTE: Seven of the 30 contaminant SSLs for the groundwater migration pathway at a DAF of 10 are below CLP RAS or CLP-equivalent detection limits. For these contaminants, special analytical services should be requested for recalibration of the instruments. For example, to measure low levels of VOCs, the gas chromatograph/mass spectrometer (GC/MS) can be recalibrated to detect at 1, 2, 5, 10, and 25 ppb.

Use of Field Methods

Where available and appropriate, field methods (soil gas surveys, immunoassays, X-ray fluorescence) can be used.

Again, for compounds other than VOCs, compositing samples is acceptable as long as it is consistent with the field methodology. If any sample concentration exceeds an SSL, further site study is required. In addition, 10% to 20% of field samples must be sent to a CLP (or equivalent) laboratory for confirmatory analysis (U.S. EPA, 1992a). Please note that field methods must be capable of achieving appropriate detection limits for most groundwater SSLs.

Depth

When measuring soil levels at the surface for the inhalation and ingestion pathways, samples should be taken at a depth of 6 inches. Additional sampling beyond 6 inches may be appropriate, depending on the contaminant's mobility, to account for geographic differences in construction practices where soil disturbances are reasonably expected. For example, in the Northeast, the ground may be excavated to 15 feet before laying the foundation and constructing the basement of a home. Excavated overburden is commonly used as fill material around the property so that contaminants that were at depth are now near the surface. Thus, it is important to be cognizant of construction practices in the area.

For the groundwater pathway, the entire soil column, from the surface to the top of the aquifer, should be sampled. For the evaluation of vertical stratification, samples should not be averaged over depth (i.e., the soil core should not be composited over depth), but rather individual samples should be evaluated at appropriate depth intervals. One soil core per exposure area may be sufficient. However, where dense nonaqueous phase liquids (DNAPLs) are suspected, soil cores may be taken more frequently.

Sampling for Background Contamination

For metals, background sampling is necessary to be certain that OSWER is not defining levels below background as of regulatory concern. If a statistical comparison of background concentration and site samples indicates that background metals concentrations are significantly above the SSLs, use of the SSLs will be of limited value, as discussed earlier.

Additional Sampling Needed for Groundwater Tier 2

To use groundwater Tier 2, site-specific soil characteristics must be determined by sampling. Parameters to measure include bulk density, porosity, organic carbon content, and water content.

Geostatistics

For large areas where the data are not widely scattered, geostatistical approaches, such as kriging, can be used to estimate sample concentration trends across the exposure area (U.S. EPA, 1989a).

For additional copies of this Fact Sheet, call the National
Technical Information Service (NTIS) at (703) 487-4650.

REFERENCES

Calabrese, E.J., H. Pastides, R. Barnes, et al. 1989. How
Much Soil Do Young Children Ingest: An Epidemiologic
Study. In: *Petroleum Contaminated Soils*, Vol. 2. E.J.
Calabrese and P.T. Kostecki, eds. pp. 363-417. Chelsea,
MI, Lewis Publishers.

Carsel, R.F., R.S. Parrish, R.L. Jones, J.L. Hansen, and R.L.
Lamb. 1988. Characterizing the Uncertainty of Pesticide
Leaching in Agricultural Soils. *J. of Contam. Hyd.* 2:111-
124.

Cowherd, C., G. Muleski, P. Engelhart, and D. Gillete. 1985.
*Rapid Assessment of Exposure to Particulate Emissions
from Surface Contamination.* Prepared for EPA Office of
Health and Environmental Assessment. EPA/600/8-85/002.

Davis, S., P. Waller, R. Buschom, J. Ballou, and P. White.
1990. Quantitative Estimates of Soil Ingestion in Normal
Children Between the Ages of 2 and 7 Years: Population-
based Estimates Using Al, Si, and Ti as Soil Tracer
Elements. *Archives of Environmental Health*, 45:112-122.

Dragun, J. 1988. *The Soil Chemistry of Hazardous Materials.*
HMCRI. Silver Spring, MD.

Truesdale, R.S. 1992. *Preliminary Soil Action Levels for
Superfund Sites.* Draft Interim Report. Prepared for Office
of Emergency and Remedial Response.   U.S. EPA.
Research Triangle Institute, Research Triangle Park, NC.

U.S. EPA. 1985. *Water Quality Assessment: A Screening
Procedure for Toxic and Conventional Pollutants.*
WPA/600/6-85/002b.

Response Activities: Development Process. EPA/540/G-
87/003.

U.S. EPA. 1989a. *Methods for Evaluating the Attainment of
. Soil Cleanup Standards.* Volume 1. EPA 230/02-89-042.

U.S. EPA. 1989b. *Risk Assessment Guidance for Superfund
Human Health Evaluation Manual: Part A.*

U.S. EPA.   1990.   *Guidance on Remedial Actions for
Superfund Sites with PCB Contamination.* EPA 540/G-
90 007. Office of Emergency and Remedial Response.
Washington, DC. August.

U.S. EPA. 1991. *Risk Assessment Guidance for Superfund.
Human Health Evaluation Manual: Part B.*

U.S. EPA. 1992a. *Guidance for Data Usability in Risk
Assessment (Part A).*

U.S. EPA.   1992b.   *Supplemental Guidance to RAGS.
Calculating the Concentration Term.*

U.S. EPA. 1992c. Synthetic Precipitation Leaching Procedure
(SPLP), Method 1312. In: *Test Methods for Evaluating
Solid Waste, Physical/Chemical Methods.* EPA Publication
SW-846. Third Edition (September 1986), as amended by
Update I (July).

U.S. EPA.   1993a.   *Background Document for EPA's
Composite Model for Leachate Migration with
Transformation Products, EPACMTP.* Office of Solid
Waste. July.

U.S. EPA. 1993b. Science Advisory Board Review of the
Office of Solid Waste and Emergency Response draft *Risk
Assessment Guidance for Superfund (RAGS), Human Health
Evaluation Manual (HHEM).* EPA-SAB-EHC-93-007.

Van Wijnen, J.H., P. Clausing, and B. Brunekreef   1990.
Estimated Soil Ingestion by Children. *Environmental
Research,* 51:147-162.